2nd Microprinting Workshop –

Emerging Trends in Microprinting: Materials, Methods and Applications

August 25-27, 2025

Hotel Elbresidenz, Bad Schandau, Germany

Abstract Booklet

Sponsors:

2^{nd} Micropringting Workshop

Emerging Trends in Microprinting: Materials, Methods and Applications

The second edition of the Microprinting Workshop 2025 promises to be an exciting event, bringing together fundamental research and industrial applications. This unique workshop will explore the latest microprinting advancements, including printed and flexible electronics, and demonstrate their transformative impact on sectors such as wearables and MEDTech.

Scope & Topics:

The microprinting workshop aims to bring together leading academic scientists, researchers, research scholars and in particular industrial players. This will create an interdisciplinary stage to exchange and share knowledge and research results on the topic related to microprinting, including printed and flexible electronics, wearables, bioprinting, biomedical devices and tissue engineering, MEMS and bioMEMS, additive micro-manufacturing, microfluidics.

Materials, Methods and Applications topics include:

– Emerging printing techniques for sub-mm sized structures
– Materials for microprinting including bioinks, nanoparticle inks or particle-free inks
– Applications for printed microstructures, e.g. in life-sciences, biotechnology or electronics
– Post-treatment techniques for printed microstructures
– Scaling of microprinting from lab to industry scale, and yield improvement
– Business trends, market projections, M&A developments, and startup activities

Scientific Organizers:

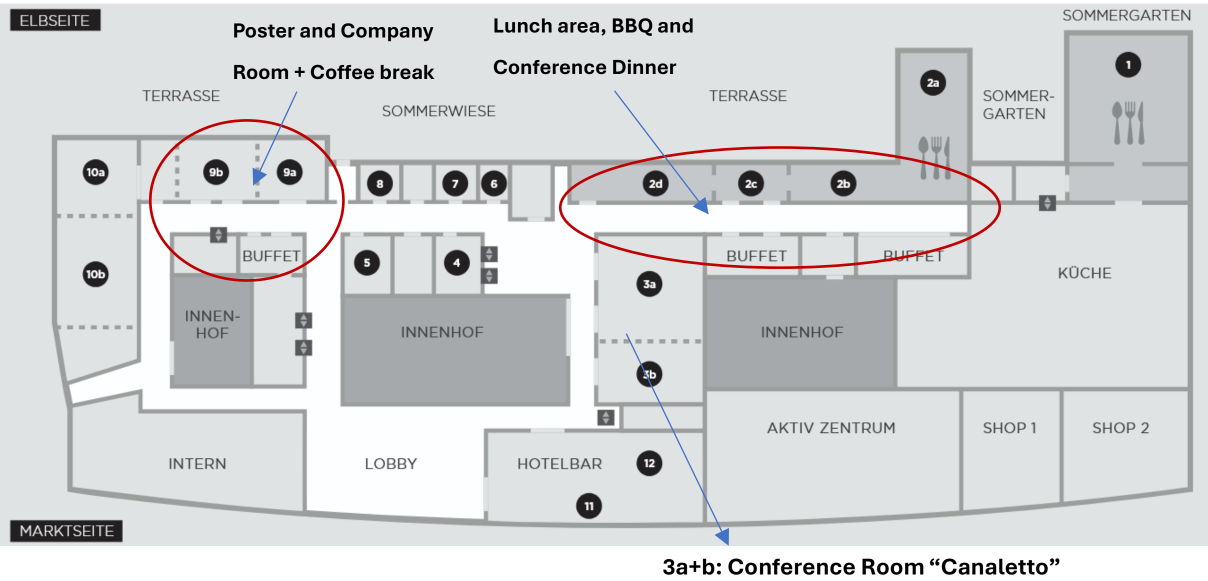
– Dr. Andreas Winkler, IFW Dresden, SAWLab Saxony & Sonojet, Germany – Conference Chair
– Dr. Brittany Newell, Purdue University, USA
– Dr. Volker Zöllmer, Fraunhofer IFAM, Germany
– Dr. Jaakko Leppäniemi, VTT Technical Research Center, Finland
– Dr. Jürgen Kosel, Silicon Austria Labs, Austria
– Prof. Gregory P. Nordin, Brigham Young University, USA
– A/Prof David Collins, The University of Melbourne, Australia

Venue:

Hotel Elbresidenz Bad Schandau near Dresden, Germany

- Wireless Internet service is available

Floor Plan:



General Information:

- Phones and Alarms
  - As a courtesy to our speakers and other attendees, please turn off your phones and alarms during sessions
- Video Recordings
  - Video recordings are strictly prohibited in the sessions and poster presentations
- Welcome Reception on Sunday, 24th August 2025, 7pm at the Bar in the Hotel Elbresidenz, Drinks at the bar are paid for individually
- Lunch on all three days, BBQ on Monday and Conference Dinner on Tuesday are included in the conference
- We will have a laptop available on site. However, you are also welcome to bring your own laptop. During the breaks, you can test the connection and the presentation.

- **Company Pitches** on Monday, 3pm
- **Poster & Company Session** (with coffee) on Monday, 3:30 pm - all industry partners have the opportunity to present their company and innovations in the poster room.
- **Special Highlight:** Hiking tour through the stunning Saxon Switzerland National Park to the "Schrammsteine" on Tuesday afternoon, offering a perfect blend of nature and science - **Bring hiking shoes (NO SNEAKERS)!**

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Program – 25th August 2025

Monday 25th August 2025

		Chair: Jaakko Leppäniemi	**Session 1: Materials Innovation for Microprinting**
	08:45	***Opening remarks***	
T1	09:00	Daniel Corzo Silicon Austria Labs, Austria	*From Molecule to Microscale: Sustainable Ink Formulation for functional printing*
T2	09:30	Jessica Zamarripa Texas A&M University, USA	*Deposition Study Towards High Cyclic Liquid Metal-Based Circuits Applied to Shape Memory Material Substrates*
T3	09:45	Sven Hujo DELO, Germany	*Investigation of Electrically Conductive Adhesives for Miniaturized SMD Components*
T4	10:00	Sarah Hoffmann KIT, Germany	*Polymer Electrolyte Membrane Fuel Cell Gas Diffusion Layers as an Application for Microprinting*
10:15 – 10:45		**Break**	
		Chair: Masoud Mahjouri-Samani	**Session 2: Emerging Microstructure Printing Techniques – Part I**
T5	10:45	Stefanie Hartmann Sonojet, Germany	*Surface-acoustic-wave (SAW) based aerosol sources for next-generation microprinting*
T6	11:15	Shingo Oshima Komori Corporation, Japan	*Solder and Cu micro-printing technology by gravure offset*
T7	11:30	Tuncay Alan Monash University, Australia	*Oscillating Microchannel-Based Atomization for High Precision Tunable Aerosol Printing*
T8	11:45	Berit Schuster Elantas, Germany Ben Hartkopp Quantica, Germany	*From analog to digital – Advancing microstructures with functional inks*
12:00 – 13:30		**Lunch Break**	
		Chair: Tuncay Alan	**Session 3: Future Applications: Biotechnology**
T9	13:30	Michael Gelinsky TU Dresden, Germany	*Combining materials, cell types and technologies for bioprinting of complex tissue models*
T10	14:00	Daniel Kranz HTW Dresden, Germany	*Biobased and Biodegradable Sensors for Monitoring of Temperature, Strain and Humidity*
T11	14:15	Kai Mattern Fraunhofer IZI, Germany	*Additive Manufacturing for the Cost-Efficient Development of High-Resolution, Point-of-Care Diagnostic Systems*
T12	14:30	Ramón Santiago Herrera Restrepo Eurecat, Spain	*Advanced Printed Sensors Integration in a Lab-on-a-Chip System for In-situ and Real-Time Water Quality Monitoring*
T13	14:45	Spencer Moore IPF Dresden, Germany	*Direct Ink Writing for prototyping of soft, multimodal and tailored bioelectronic interfaces*
	15:00	**Announcement + Company Pitches**	
	15:30	**Poster + Company Session (with coffee)**	
	P1	Christoph Folgner HZDR, Germany	*Silicon Fleece Anodes as Components of Lithium-Ion Batteries*
	P2	Shingo Oshima Komori Corporation, Japan	*Next-gen printing for high precision and mass production*
	P3	Nico Arnold IFTE / TU Dresden, Germany	*Please, Fold the Line: Designing Flexible Electronics Using Open-Source Software*
	P4	Raouf Belloum HZDR, Germany	*Enhancing Inkjet Print Quality of Metal-Organic Decomposition Ink on Glass Surfaces*
	P5	Anete Sapne University of Latvia, Latvia	*Inkjet printing for integrated heterogeneous photonics*
	P6	Tadahiro Furukawa Yamagata University, Japan	*Conductive Inks for Thermoforming and Molding Conditions*
	P7	Yannik Mahlau Leibniz University Hannover, Germany	*FDTDX: Electromagnetic Simulation and Inverse Design of Nanophotonic Structures*
	P8	Alexander Blümel JOANNEUM Research, Austria	*Aerosol Jet Printing and Capillary Assisted Inkjet Printing as High-Resolution Deposition Techniques for Fabrication of Electrodes in Microfluidic Applications*
	P9	Nowab Reza MD Ashif KIT, Germany	*Extrusion Printing of RF Coplanar Waveguides: From Concept to Realization with Off-the-Shelf Equipment*
	18:00	**Barbecue**	

T1

From Molecule to Microscale: Sustainable Ink Formulation for functional printing

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Type of presentation: invited talk

Functional inks are at the heart of additive manufacturing technologies, both at macro and micro scales. Their formulation directly influences film formation, resolution, substrate compatibility, and ultimately the performance of printed devices. By adjusting parameters such as solubility parameters, rheology, and molecular bonding, organic materials can be precisely deposited by inkjet, aerosol-jet, and 3D printing. Bioderived solvent systems offer an environmentally responsible alternative to conventional processing of organic electronics, while maintaining the solubility and deposition behavior required for high-performance. Controlled drying kinetics and selective solvent interactions enable fine-tuning of active layer morphologies, critical for multilayer structures in sensors, optoelectronics, and energy storage components. These strategies have made it possible to fabricate fully printed systems on flexible and even biodegradable substrates. Applications range from miniaturized photodetectors to wearable biosensors that integrate microfluidics, power sources, and signal readout. This work highlights how sustainable ink design and process control together shape the next generation of functional microprinted devices.

References

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2. Bihar, E, et al D. *Fully Inkjet-Printed, Ultrathin and Conformable Organic Photovoltaics as Power Source Based on Cross-Linked PEDOT:PSS Electrodes.* **Advanced Materials Technologies**, 5(4), 2000226 (2020).
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5. C. Amruth, et al. *Micro-3D Printed Conductive Polymer Composite via Two-Photon Polymerization for Sensing Applications*. **Advanced Materials Technologies**, 9, 2400290 (2024).

Deposition Study Towards High Cyclic Liquid Metal-Based Circuits Applied to Shape Memory Material Substrates

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Type of presentation: contributed talk

Sensors and circuits are essential components in electronic systems, enabling functionalities such as signal/power transmission, heat delivery, and environmental state measurements, among others. Traditional sensors and circuits, made from rigid materials and designed for fixed positions, cannot conform to irregular shapes and morphing structures. To overcome these limitations, a new generation of highly flexible sensors and circuits has emerged, capable of detecting physical changes even when interfacing with non-rigid geometries. These flexible components must be sensitive, consistent over many deformation cycles, able to withstand high local strains, conformal to surfaces, and require minimal power. Their development drives the need for new materials and fabrication techniques, with eutectic gallium-indium (EGaIn) liquid metal (LM) showing strong potential due to its ability to remain in a liquid state at ambient temperature and adapt under deformation. It has excellent thermal and electrical conductivity and minimal degradation in electrical performance [1]. Researchers have used LM to create stretchable interconnections, strain gauges, heaters, thermocouples, and self-healing circuits [2]. To fabricate LM sensors and circuits, a repeatable patterning method that provides high-resolution and accounts for LM wetting behavior is essential. This work focuses on developing a new fabrication method using lithography stencils that are 3D printed from a magnetic filament and spray printing. The LM patterning technique will be used to create high-strain sensors for solid-state actuators made from shape memory polymers (SMPs), shape memory alloys (SMAs), or similar materials. These sensors and circuits will reveal the electromechanical and thermomechanical coupling mechanisms in these actuators. Additionally, they could be applied to wearable electronics, medical devices, soft robotics, monitoring aircraft wing deflection, and morphing vehicles [2].

References

[1] Q. Wang, Y. Yu, and J. Liu, “Preparations, Characteristics and Applications of the Functional Liquid Metal Materials,” 5 2018.
[2] M. D. Dickey, R. C. Chiechi, R. J. Larsen, E. A. Weiss, D. A. Weitz, and G. M. Whitesides, “Eutectic gallium-indium (EGaIn): A liquid metal alloy for the formation of stable structures in microchannels at room temperature,” Advanced Functional Materials, vol. 18, pp. 1097–1104, 4 2008.

Investigation of Electrically Conductive Adhesives for Miniaturized SMD Components

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Type of presentation: contributed talk

The manufacturing and processing of solder materials face significant challenges when the edge lengths of surface-mount devices (SMDs) fall below 150 µm. In FlipChip designs, such as miniLEDs, this results in a reduced pad footprint and narrower spacing between them. Traditional soldering techniques are reaching their limits in these scenarios, underscoring the growing importance of exploring alternative connection methods.

DELO Industrial Adhesives has conducted comprehensive laboratory-scale tests to evaluate the benefits of adhesives as functional materials. A particular focus was placed on materials that are conductive in only one direction, inherently preventing short circuits. Such anisotropically conductive adhesives potentially offer significant advantages over traditional soldering techniques, especially in reducing component spacing and promoting miniaturization.

To conduct the investigation, a specially designed printed circuit board (PCB) was employed to analyze the behavior of individual miniLEDs as well as in a 5x5 array configuration. Initial analyses concentrated on mechanical properties, examined under various conditions such as 85 °C at 85% relative humidity and at 120 °C for up to 500 hours, using shear strength tests. The electrical conductivity was evaluated through comparative measurements with soldering materials, including the analysis of voltage/current characteristics and resistivity measurements.

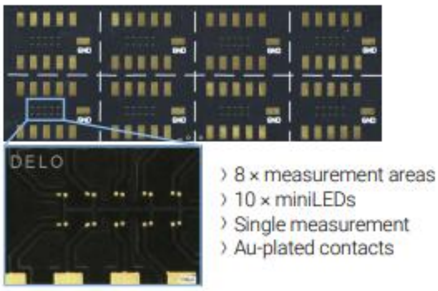

Figure 1: First main section of DELO test board with gold coated conductive pads for single miniLEDs measurements in eight different areas, each have ten dedicated positions for miniLEDs, to perform single measurements with measurement tips

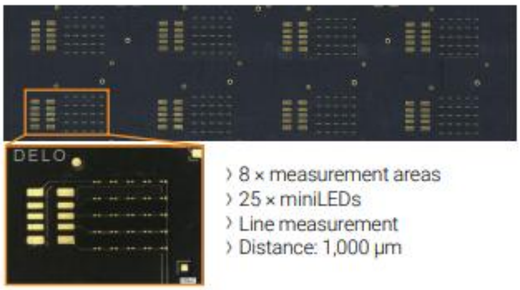

Figure 2: Second main section of DELO test board with gold coated conductive pads for array miniLEDs measurements in eight different areas, each have 25 dedicated positions for miniLEDs, to perform daisy chain measurements with measurement tips or external source meter

The test results indicate that DELO DUALBOND AC2264 is a suitable alternative to conventional solder materials, providing a reliable electrical and mechanical connection for small SMD components. Especially for applications requiring high thermal and mechanical resilience, the use of adhesives opens new avenues.

In addition to investigating mechanical and electrical properties, transparent materials for flexible and transparent substrates are currently under evaluation. These materials could potentially contribute significantly to the development of flexible displays and other optoelectronic applications in the future.

In summary, the use of electrically conductive adhesives presents a promising alternative to traditional connection techniques, particularly in applications requiring high precision and reliability with minimal component spacing. Ongoing research and optimization of such materials could significantly contribute to advancements in electronics manufacturing.

References

https://www.delo.de/whitepaper-microled-display-manufacturing

Polymer Electrolyte Membrane Fuel Cell Gas Diffusion Layers as an Application for Microprinting

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Type of presentation: contributed talk

The gas diffusion layer (GDL) of a polymer electrolyte membrane fuel cell (PEMFC) plays a crucial role in the overall fuel cell performance. It determines the uniformity of reactant gas distribution, facilitates the electrical conductivity and manages product water removal. This work investigates the potential of microprinting techniques for GDL fabrication.
Simulative and experimental tests were conducted to compare the properties and performance of a commercial fiber GDL and a GDL designed for additive-subtractive manufacturing on the basis of selective laser melting (SLM). The designed structure was fabricated by laser perforation and subsequent stacking of three 40 µm thick graphite layers with an area of 1 cm^2. The perforations in the layers had diameters of 20 µm, 50 µm, and 100 µm, and were stacked with a gradient from smallest to widest diameter as depicted in Figure 1. The designed three-layered GDL, as well as the reference fiber GDL, were evaluated by fuel cell performance tests of a 1 cm^2 single-cell setup.
The design and experimentally tested fabrication method are presented, along with a further evaluation of applicable microprinting techniques investigating the potential and challenges of each fabrication method for GDL fabrication. It is shown that the freedom in design gained through using additive-subtractive manufacturing allows for structures with lower through-plane electrical resistance and improved overall performance.

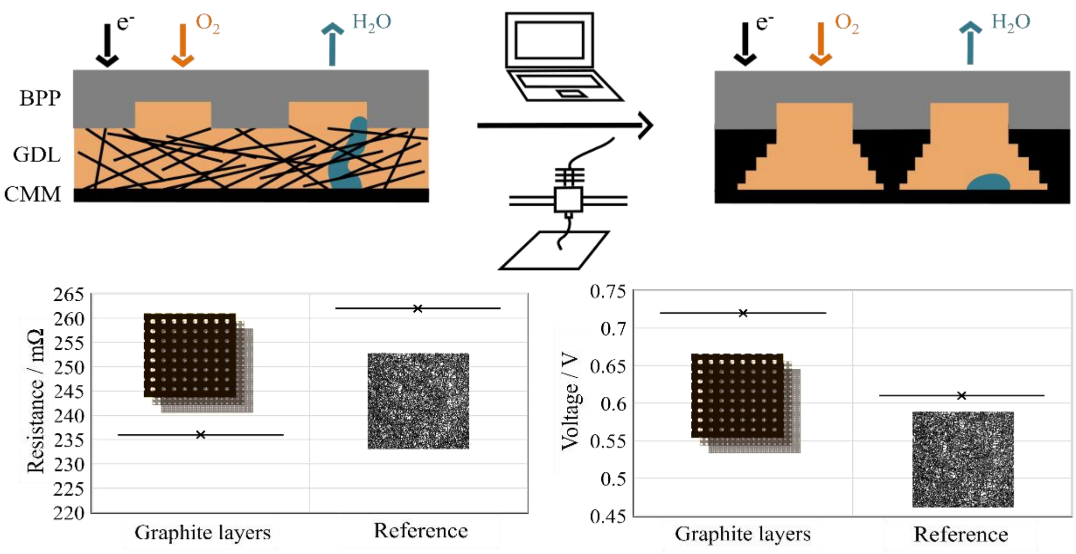

Figure 1: Simulated electrical through-plane resistance and experimentally measured fuel cell voltage at 0.5 A for the designed three-layered structure and the reference GDL.

Surface-acoustic-wave (SAW) based aerosol sources for next-generation 3D microprinting

Stefanie Hartmann[1,2*], Mehrzad Roudini[1,2], Yara Alsaadawi[1], Iman Frozanpoor[1], Bahar Geramian[1], Uhland Weißker[1,2], Paul Günther[1,2], Edwin Zschetzsche[1], Andreas Winker[1,2]
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Type of presentation: invited talk

Microprinting technologies are enabling a new class of applications that require ever more precise, scalable, and material-flexible deposition methods, especially for 3D-structured surfaces and complex geometries. At the core of this evolution lies the need for new aerosol printing technologies that combine high resolution, robustness, and integration potential. In this talk, we present a novel class of surface-acoustic-wave (SAW)-based aerosol printheads tailored for next-generation 3D microprinting.

Since the first demonstration of a SAW aerosol generator by Kurosawa et al. 30 years ago [1], many efforts have been taken to enhance fundamental understanding as well as application-related development of this effect. At IFW and SONOJET, we have developed the future generation of compact, integratable SAW-based atomizers and aerosol printheads to pave the way towards their industrial applicability and commercial exploitation [2, 3]. The SONOJET system creates directed aerosol jets with adjustable droplet sizes ranging from sub-micron to tens of microns, operates without moving parts, nozzles, or meshes, and is capable of handling a wide spectrum of fluids from aqueous and organic inks to viscous suspensions and even biological media.

At the heart of our atomizers are piezoelectric $LiNbO_3$ chips featuring on-chip integrated interdigital transducers and microfluidic channels enabling the precisely controllable liquid supply into the acoustic wave field to create a defined aerosol. Upon aerodynamic focusing, the aerosol beam can be directed onto the target substrate, enabling contactless printing on arbitrarily shaped 3D surfaces with working distances of several centimeters.

Compared to conventional pneumatic or ultrasonic aerosol printers, the SAW-based system is significantly more energy-efficient, requires only minimal ink volumes (µl range), and offers fast chip exchange and integrated thermal management. The print heads are especially suited for Direct-to-Shape (DTS) applications and enable functional microstructures such as conductors, antennas, or sensors to be printed directly onto 3D-printed parts, curved housings, or flexible electronics.

This approach opens new possibilities in printed electronics, advanced packaging, and microscale additive manufacturing, offering a scalable and versatile toolset for industrial and research environments alike.

References

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Solder and Cu micro-printing technology by gravure offset

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Type of presentation: contributed talk

In recent years, electronic devices have become more multifunctional and high-performance, particularly in the mobile sector, there is a demand for miniaturization and higher density of internal components. However, due to the underdevelopment of surface mounting technology (SMT), this requirement has not been met. In addition, there is a need to reduce the environmental impact of the manufacturing process. The plating and etching processes have a high level of waste fluid and material loss. Therefore, we have developed two technologies using gravure offset printing: one is a micro solder paste printing technology, and the other is a micro wiring formation technology using copper paste.

Fig. 1 shows an example of mounting a micro-LED using gravure offset printing. This LED has a long side of 36 μm and a short side of 18 μm. The size of the printed solder bumps is Φ18μm and the gap between the electrodes is 8μm. The micro-LED was mounted using the laser lift-off method. The solder paste used was specially formulated to be compatible with the gravure offset printing method, using a particularly fine Type 10 solder. Furthermore, this technology is extremely small compared to conventional SMT, so we believe it can be converted to SMT micro- components mounting and high-density mounting.

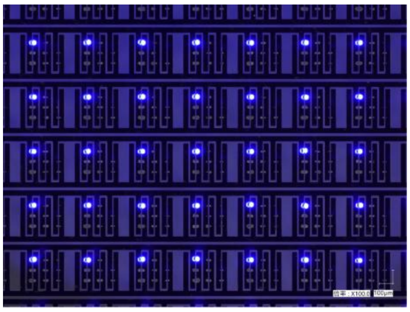

Fig.1 micro-LED mounting

Fig. 2 shows fine Cu wiring formed by gravure offset printing, with line & space of 7μm12μm. Compared to the silver paste conventionally used in the printing method, this paste has superior ion migration properties and has advantages in micro areas, and we are planning to use it for applications such as substrate wiring substitution and bump formation.

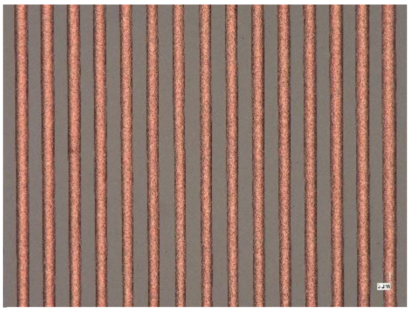

Fig.2 Cu paste wiring

References

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Oscillating Microchannel-Based Atomization for High Precision Tunable Aerosol Printing

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Type of presentation: contributed talk

Aerosol printing enables high-resolution patterning of functional materials for microelectronics, sensors, and biomedical devices. However, key challenges remain in achieving fine line widths and reducing overspray. Current systems rely on focusing a large aerosol plume into a narrow region, which, while capable of producing features approaching 5 μm, often requires complex mechanisms [1]. Improved methods are needed to enhance resolution, reduce overspray, and support a wider range of materials.
Here, we propose a new aerosol technology offering precise control on the atomization process to address these issues. Our approach utilizes a microfluidic chip with high-aspect-ratio silicon microchannels mounted on a piezoelectric transducer. When targeted ultrasonic vibration is applied, the liquid to be aerosolised is rapidly drawn to the ejection site, where critical-amplitude capillary waves lead to a singular and monodisperse aerosol stream [2] (Fig. 1a). The median droplet diameter can be precisely controlled on demand by adjusting the oscillation frequency [3], while the aerosol flow rate can be modified through actuation parameters. Here we show that we can produce a narrow jet of aerosol consisting of a single stream of 4.5 μm diameter droplets, with a geometric standard deviation (GSD) of 1.2 (Fig. 1b) without needing complicated focusing strategies. This has the potential for: lower wastage of aerosol inside focusing stages, less droplet merging, less chance of nozzle clogging, and less energy (heat) input during aerosolization.
Indeed, we show that using only a carrier gas (Fig. 1c, d) can accelerate the aerosol stream into a steady, directional, high-speed jet. This enables deposition of small features, enhancing printing precision and resolution. Furthermore, unlike conventional aerosol jet printers which cannot rapidly alter the output stream due to drawing from a large volume of aerosol, our approach can initiate and cease aerosol generation within 5 microseconds, which is crucial to enable rapid changes in printed patterns with minimal overspray. The microchannel-based aerosolization mechanism operates at low power and low shear, reducing thermal load and mechanical stress, making it ideal for the bioprinting of living cells and other shear-sensitive materials.

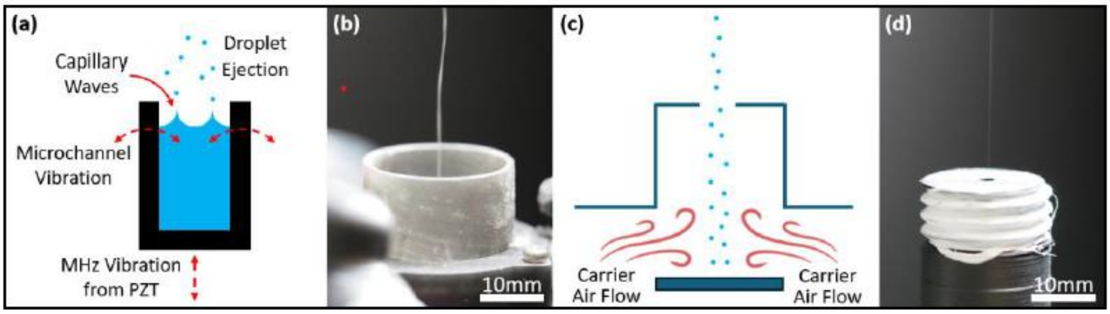

Figure 1: (a) schematic of the droplet ejection mechanism from a high aspect ratio microchannel, (b) photograph of the narrow aerosol plume without focusing, (c) schematic of carrier gas flow over the device

to accelerate the aerosol plume into a jet, (d) photograph of the experimentally focused jet through a 3mm diameter aperture.

References

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From analog to digital – Advancing microstructures with functional inks

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Type of presentation: contributed talk

This talk explores the transition from analog to digital printing technologies for the application of functional microstructures using conductive inks. The first part highlights fine-line printing via screen printing, showcasing ELANTAS' capabilities in producing precise, functional layers. The second part introduces the digital printing technology developed by Quantica, emphasizing its potential for jetting high viscosity materials. Finally, initial trials combining both approaches are presented, offering insights into process compatibility and an outlook into future application possibilities.

Combining materials, cell types and technologies for bioprinting of complex tissue models

***Michael Gelinsky*[1*]**

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Type of presentation: invited talk

Three dimensional bioprinting has developed tremendously within the last ca. 10 years, both concerning available technologies and biomaterials that can be utilized. In our lab we are especially interested in the development of novel bioinks for extrusion bioprinting that combine good printability and buildability with high cytocompatibility and in combining different additive manufacturing technologies in one joint printing process. In the field of bone bioprinting we are combining self-setting calcium phosphate bone cements that provide a stiff mineralized framework with bioinks supplemented with either human blood plasma [1] or egg white [2-4]. Such constructs can be cultivated over extended time periods. By utilizing core/shell bioprinting, i.e. simultaneous extrusion of two (bio)inks through a coaxial nozzle we could immobilize growth factors, relevant for either chondral (TGF-β) or osteogenic (BMP-2) differentiation in a spatial defined manner in bilayered osteochondral constructs [5].

In other studies, we have established models for the liver sinusoid by applying core/shell bioprinting with a hepatocyte cell line integrated in the shell and a co-culture of endothelial cells and fibroblasts in the core [6]. The formation of a well-defined microvascular network could be observed in the core as well as a supportive effect of the core compartment on the bioprinted hepatocytes.

Overall, this strategy allows to control both the micro-environment of the cells and the macroscopic properties of the constructs and to manufacture tissue models with enhanced relevance.

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T10

Biobased and Biodegradable Sensors for Monitoring of Temperature, Strain and Humidity

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Type of presentation: contributed talk

The increased use of smart technologies in agriculture, environmental applications, medicine, etc. has resulted in a growing demand for the use of sensors. These sensors are predominantly made from fossil-based, non-degradable and non-biocompatible materials, contributing to the increasing challenges of WEEE [1-3]. The necessity for sustainable sensors is therefore paramount. Our approach replaces conventional materials with commercially available, biobased, and biodegradable alternatives by developing a gelatin-based sensor. Gelatin has been chosen as a model system for a polypeptide-based sensor due to its commercial availability in defined qualities. The sensitive layer is made from gelatin with tannic acid (crosslinker), glycerol (plasticiser) and carbon black (conductive additive). Silver electrodes are printed onto the sensitive layer using screen printing.
In this study, we investigated the influence of bending, temperature, and humidity on the electrical resistance. Elongation was analyzed via three-point bending tests at room temperature. For thermal characterization, temperature was reduced from 35 °C to 5 °C in 5 K steps, with each step held for 10 minutes. The effect of air humidity (100–5000 ppm) on electrical resistance was examined using a gas measurement setup [4]. While the influence of humidity is in an order of 0,1 Ω/ppm, a range well known from literature [4], strain and temperature caused weaker dependencies. Strain and temperature sensitivity were found to be in the range of ca. 2.7 Ω/N and 5 Ω/K, respectively. It is very likely that the sensitivity and the contacting of the sensitive layer could be further enhanced through optimisation of the distribution of carbon black in the matrix and optimized screen printing of the electrodes, respectively.
The findings of the present study demonstrate the viability of fabricating these sensors through the utilisation of biobased and biodegradable materials as the primary constituents.

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Additive Manufacturing for the Cost-Efficient Development of High-Resolution, Point-of-Care Diagnostic Systems

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Type of presentation: contributed talk

The development of modern point-of-care (POC) diagnostic systems demands flexible, rapid, and precise manufacturing techniques. Our hybrid approach combines high-resolution SLA 3D printing (50 µm resolution) with subsequent hot embossing to structure thermoplastic materials—a process well-suited for both rapid prototyping and scalable production.
A key feature is the ability to create 2.5-dimensional freeform structures with complex geometries, including radii, angles—all in a single process. Through targeted thermal bonding, these structures can be fully encapsulated and integrated into multilayer designs. This allows for the simultaneous fabrication of micro- and macro-scale features within the same system, while also enabling the successful integration of functional components such as membranes or filter media. Another major advantage is the capability to combine different thermoplastics within one device. By bonding and structuring multiple materials simultaneously, a wide range of optical, mechanical, and chemical properties can be addressed in a single system. The choice of thermoplastic end materials is nearly unrestricted—ranging from conventional to bio-based polymers, including flexible substrates, which have already been successfully structured.
Thanks to this approach, fully functional POC systems can be developed within two weeks -from concept to a new design iteration - at a cost reduction of up to 100 to 1000 times compared to cleanroom-based or other rapid prototyping fabrication techniques [1]. This contribution presents various example systems, including lateral-flow-based assays [2], electrochemically readable flexible platforms with integrated plasma separation, and a two-component microfluidic platform for colorimetric assays. Each system demonstrates the potential of this flexible manufacturing strategy to enable a new generation of medical diagnostic solutions.

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T12

Advanced Printed Sensors Integration in a Lab-on-a-Chip System for In-situ and Real-Time Water Quality Monitoring

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Type of presentation: contributed talk

Water monitoring has emerged as a critical global issue, as water remains an essential resource for millions of people worldwide. The increase in water pollution driven by industrial and agricultural activities has been accelerating since the 17th century, prompting a rise in environmental regulations and public health concerns due to the harmful effects of contaminated water. [1] Despite the amount of sensing tools using different technologies, there are still limitations in cost-effective systems for generating valuable real-time information on water quality. Our approach uses Lab-on-a-Chip system that offers distinct advantages, such as reducing sample volumes to microliter scales and enabling continuous monitoring with automated data collection and processing. However, most existing LOC devices are confined to laboratory research and fail to reach the market due to high production costs and limited scalability. [2–4] In response to these challenges, we propose a novel and sustainable platform capable of parallel measurement of key water quality parameters—including conductivity, pH, selective ion detection, dissolved oxygen, among others. [5] Our platform integrates microfluidic technology with screen-printed sensors, fabricated using sustainable materials. Our manufacturing process employs automated systems that can produce hundreds of electrodes rapidly, which are easily assembled into reusable microfluidic devices. We have demonstrated the capability to detect water analytes at low concentrations, with long-term stability and support for continuous monitoring. We envision scaling up this technology for commercialization, making advanced water monitoring more accessible and sustainable.

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T13

Direct Ink Writing for the Prototyping of Soft, Multi-modal, and Tailored Bioelectronic Interfaces

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Type of presentation: Contributed talk

Here we will describe our efforts to adapt extrusion-based direct ink writing techniques to support the fabrication of soft, electronic systems with applications in bioelectronics.
We combine silicone inks, conductive particles and discrete electronic components to print modules designed to enable electrical, microfluidic, and thermal functionality. Stacking these base modules allows us to rapidly assemble prototypes of bioelectronic implants such as electrode arrays adapted for interfacing with the brain, spinal cord and peripheral nerves.
As a proof of concept, we developed a system consisting of a printed implant and supporting hardware that deploys rapid focal cooling and electrophysiological recording on the cortical surface in a rat model of epilepsy.
3D printing approaches has directly enabled this advance in the assembly of practical soft systems for the delivery of tailored, multi-modal neural interfacing.

Silicon Fleece Anodes as Components of Lithium-Ion Batteries

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Type of presentation: poster

Lithium-ion batteries are essential for the transition to sustainable energy, focusing on energy density, safety, and resource availability. Silicon (Si) is a promising anode material due to its theoretically tenfold increase in capacity compared to traditional graphite. However, its significant intrinsic volume expansion (up to 300%) during the lithiation results in rapid degradation due the mechanical stress. Current manufacturing methods primarily rely on vacuum processes, limiting scalability and efficiency.

An innovative manufacturing process for Si anodes is developed, which addresses these limitations and considers the requirements of an energy-efficient and sustainable fabrication process. The method involves grinding silicon particles, preferably purchased from solar cell recycling, into a printable ink, which is processed via inkjet printing for infiltration into a conductive fleece, followed by ultrafast thermal curing (flash lamp annealing or laser sintering). Because of the milliseconds time scale, this thermal treatment is advantageous in terms of energy and process time saving [1]. This approach produces flexible anode structures while mitigating degradation associated with volume expansion, thus enabling a cost-effective production process. The formation of alloy phases (CuxSiy) at the interface between Si and the active material enhances the long-term stability of the anodes [2].

Compatible NMC cathodes with high areal capacities (~3 - 12 mAh/cm2) are fabricated for electrochemical full cell tests. The resulting Si anodes are structurally characterized and tested in coin cell configurations, targeting a specific capacity exceeding 5 mAh/cm^2 and energy densities above 300 Wh/kg, with a targeted lifespan greater than 100 cycles. This work represents a notable advancement in lithium-ion battery technology.

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Next-gen printing for high precision and mass production

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Type of presentation: poster

In the field of microprinting, we offer three types of printing machines. The first is a gravure offset printing machine, the second is a vacuum plugging (filling) machine, and the third is a gapless screen-printing machine.
Gravure offset printing is most effective for printing in the range of a few micrometers to 100 micrometers and has traditionally been used to produce touch panels and membrane switches. We have developed this gravure offset printing machine to achieve a printing position accuracy within ±5 micrometers. Additionally, the development of a continuous printing mechanism has established mass production capabilities for thousands of sheets. For these reasons, our gravure offset printing machine can be used for the application of adhesives for micro-LEDs, high-density mounting of surface mount components, and the formation of fine wiring on glass, wafers, or films in mass production.
The vacuum plugging machine is a printing machine that can print substrates and ink in a vacuum state, primarily used for filling vias in package substrates. Utilizing this, we are exploring the filling of through-glass vias (TGV) in glass interposers through printing. Generally, TGV filling is done using plating methods, but plating on glass substrates results in poor adhesion and compromises the reliability of the substrate. Additionally, the process takes several tens of hours and is not sustainable. By using this vacuum coater to fill TGVs with Cu paste, these issues can be resolved.
The gapless screen-printing machine allows for printing with zero clearance (gap) between the substrate and the screen, which was previously present in traditional screen printing. This eliminates screen stretching during printing, improving both printing accuracy and mass production capabilities.
We will apply these technologies to micro-printing to achieve a more sustainable society.

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P3

Please, Fold the Line: Designing Flexible Electronics Using Open-Source Software

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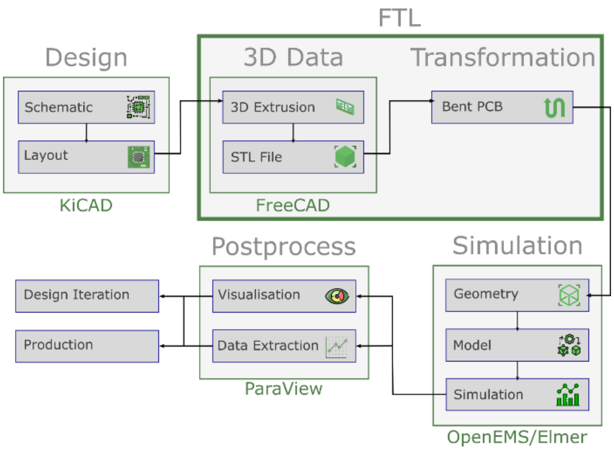
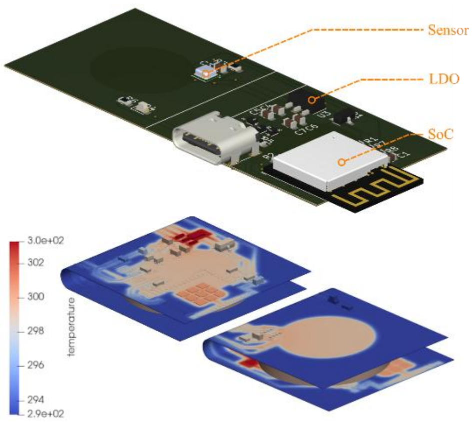
Type of presentation: poster

Predicting the properties of flexible printed circuits (FPCs) before production is a significant challenge in their development. Traditional design flows model FPCs in a flat state, yet simulations of the actual bent shape of the circuits are more effective in forecasting their behavior in real-world applications. Currently, only proprietary tools are available for simulating these 3D geometries, with no open-source alternatives. This paper introduces a novel open-source software tool that bridges this gap by transforming two-dimensional layout data from KiCad files into three-dimensional bent geometries. This transformation is achieved through segmentation and meshing techniques, enabling accurate verification of circuit parameters via simulation. The software facilitates these simulations by generating the necessary input files, thus supporting a comprehensive open-source design and verification workflow. This work not only enhances the accessibility of FPC design and simulation but also underscores the broader applicability of open-source solutions for printed circuit board design.





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P4

Enhancing Inkjet Print Quality of Metal-Organic Decomposition Ink on Glass Surfaces

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Type of presentation: poster

As glass sheets become thinner and more flexible, they are emerging as a promising substrate for wearable and flexible electronics. However, the integration of inkjet printing—one of the key technologies in flexible electronics—represents significant challenges. Glass surfaces are notoriously difficult to print on, as inks often exhibit issues such as dewetting or excessive spreading. In this poster, we present an optimized pre-treatment process for glass surfaces without the need of special ink promoters along with a print-data optimization routine that together result in significantly improved print quality for small feature sizes. Metal-Organic-Decomposition (MOD) inks were used on various surfaces.

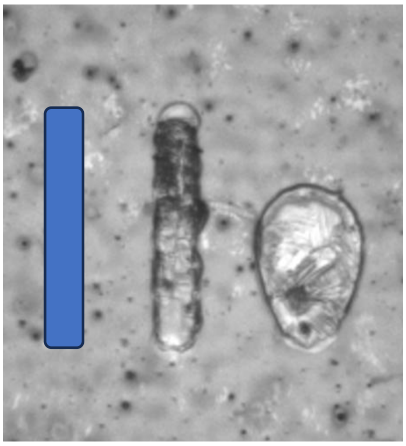

Fig. 1. From left to right: Targeted interconnect-print design, print with optimization routine, print without optimization routine

P5

Inkjet printing for integrated heterogeneous photonics

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Type of presentation: poster

With advancements in communication technologies, the demand for faster data transmission and processing devices has grown significantly. This has driven increased interest in the development of optical signal processing devices. Current research in integrated photonics focuses on addressing two key challenges: identifying materials with strong nonlinear optical (NLO) properties and refining the process of heterogeneous integration.
Currently, multiple photonic platforms are being developed, including single material platforms (e.g., Si, InP), hybrid integrated photonics and heterogeneous integrated photonics. Although the workflow for single material structures is well developed, no single material provides all the necessary photonic components. While hybrid platforms can expand the number of available components, combining multiple inorganic materials and their workflows remains challenging. The heterogeneous polymer platform can address these issues, as polymers can be used in host-guest systems, and the fabrication of polymer photonic devices is more cost-effective and simpler compared to silicon and other inorganic platforms. Additionally, polymers have demonstrated high NLO efficiency, enabling a wide range of photonic applications.
At the Institute of Solid State Physics (ISSP) we are working on selecting new materials for photonic applications and establishing workflows for device fabrication.
In this work, inkjet printing is used to fabricate the active polymer element in an electro-optic modulator. This method offers the advantages of being compatible with other workflows while also using less material than other wet casting methods. To create test structures, trench waveguides were prepared in quartz and SiO_2 on Si substrates using optical lithography and dry etching. Inkjet printing was then employed to fill the prepared structures with solutions of polysulfone, anisole, and novel organic compounds synthesized at Riga Technical University. After establishing the workflow for polymer printing on test samples, the polymer inks were printed on chips with electro-optic modulator structures that were prepared in IMEC. This talk will focus on the key parameters influencing the quality of printed structures and the workflow established at ISSP for polymer printing.

This work is done in the frame of the European Union's Horizon Europe research and innovation program under grant agreement No. 101070332 (PHORMIC).

Conductive Inks for Thermoforming and Molding Conditions

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Type of presentation: poster

We started developing in-mold electronics with OES in the "ORIGAMI Project". The first prototype is shown in Figure 1. In this prototype, the touch electrode and LED were embedded in resin, and the LED corresponding to the touched position turned on. One of the key technologies in in-mold electronics is thermoforming, in which a flat sheet with electrodes or other components is deformed into a three-dimensional shape. This technology has been advanced as a decorative technology, but in the electronics field, it is necessary to deal with resistance changes and wiring disconnection due to electrode elongation, and it is also necessary to develop a technology for attaching LED chips and/or other semiconductor chips to three-dimensional shapes.

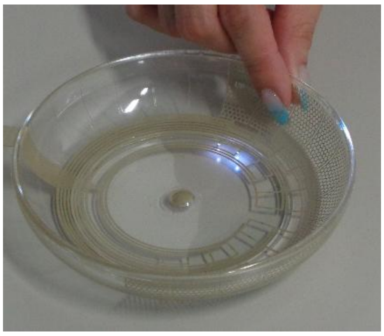

Fig. 1 First prototype sample

We first evaluated a silver paste (manufactured by Fujikura Kasei). Next, polyaniline ink (manufactured by Idemitsu Kosan) was evaluated. The pattern printed with silver paste increased in electrical resistance around the 1.6 times extension, and further extension resulted in disconnection. On the other hand, the polyaniline pattern could be extended 2.5 to 3 times. This is very advantageous for product design. However, this polyaniline pattern did not conduct electricity, so the pattern was plated to function as wiring. Plating is cost-prohibitive and increases environmental impact, but it can significantly reduce electrical resistance. An important issue is to develop a final product that takes advantage of the characteristics of each ink.

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FDTDX: Electromagnetic Simulation and Inverse Design of Nanophotonic Structures

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Type of presentation: poster

The microprinting of three-dimensional photonic structures has revolutionized nanoscale fabrication but brings significant design challenges that traditional manual approaches struggle to address. Conventional design workflows rely heavily on intuition, trial-and-error, and parametric sweeps, making them labor-intensive, time-consuming, and often limited to simple geometries. Therefore, automated inverse design methodologies that can efficiently navigate vast parameter spaces are essential for fully exploiting the capabilities of modern microprinting technologies. To address this need, we present FDTDX [Sch25], an open-source python package for electromagnetic simulation and inverse design of photonic nanostructures using the Finite-Difference Time-Domain (FDTD) method. Built on the JAX framework, FDTDX combines high-performance GPU acceleration with automatic differentiation, enabling gradient-based optimization of complex three-dimensional electromagnetic structures. The package leverages the time-reversibility property of Maxwell's equations to implement a memory-efficient automatic differentiation method for computing gradients, significantly reducing the computational resources required for inverse design tasks. Our implementation demonstrates excellent scaling on multi-GPU systems, handling simulations with billions of grid cells. Benchmark tests show that FDTDX is currently the fastest open-source FDTD software [Mah25]. We demonstrate the capabilities of FDTDX through several inverse design examples, including robust coupling elements and sharp waveguide corners for fabrication with Two-Photon-Polymerization.

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Aerosol Jet Printing and Capillary Assisted Inkjet Printing as High Resolution Deposition Techniques for Fabrication of Electrodes in Microfluidic Applications

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Type of presentation: poster

In recent years, Microfluidic devices have been in focus of research and development, and applications include environmental monitoring, Point-of-Care diagnostics or Lab-on-Chip systems.
For these applications, different sensor principles are applied, such as optical, acoustical or electrochemical detection methods. For electrochemical sensing approaches in particular, deposition of highly defined electrodes with sufficient conductivity is crucial.
Here we present two approaches for deposition of electrodes for use in microfluidic devices, namely Aerosol Jet Printing of in-house developed self-reducing silver inks, and capillary assisted inkjet printing.
For the first method, highly defined electrodes with a line width of approx. 15 µm have been deposited over the edges of microfluidic channels by means of Aerosoljet Printing. Apart from the achieved high resolution, further advantages include the relatively low curing temperature which is compatible with most thermoplastics, the excellent conductivity and the good wetting and adhesion properties, even on hydrophobic substrates.
For the second method, silver ink has been inkjet-printed into pre-structured reservoirs connected to highly defined channel structures fabricated by Nano Imprint Lithography (NIL). After deposition of the ink, the channels are filled by capillary forces, thus achieving feature resolutions smaller than 10 µm.

P9

Extrusion Printing of RF Coplanar Waveguides: From Concept to Realization with Off-the-Shelf Equipment

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Type of presentation: poster

Coplanar waveguides (CPWs) are fundamental components for radio frequency electronic and photonic systems used in a variety of applications in telecommunications, radar systems and wireless communication, but their fabrication often involves complex and costly processes.
This study presents a low-cost, accessible method for CPW fabrication using a commercial extrusion dispensing system and a screen-printable silver ink. CPWs were printed on alumina substrates using off-the-shelf equipment. Dimensional characterization revealed excellent reproducibility with minimal variation in line width and gap spacing [1]. Electromagnetic simulations and vector network analyzer measurements demonstrated strong agreement, confirming low insertion loss (<1 dB) and return loss better than 10 dB up to 33.8 GHz for a 4 mm line [2]. Compared to other methods such as aerosol jet or inkjet printing, this approach offers competitive performance with significantly simplified process chains and reduced equipment costs [3, 4]. This approach demonstrates a digital manufacturing route for RF transmission lines that combines cost-efficiency, simplicity, and competitive performance.

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Program – 26th August 2025

Tuesday 26th August 2025

	Chair: Darragh Walsh		**Session 4: Scaling of Microprinting - Part I**
	8:45	**Announcements**	
T14	09:00	Dr. Kai Keller Notion Systems, Germany	*Making an impact: Scaling digital, additive processes into electronics production*
T15	09:30	Steffen Günther Fraunhofer FEP, Germany	*Roll-to-roll Nano-Imprinting Processes for Functional Surfaces Using Electron Beam Crosslinking*
T16	09:45	Jaakko Leppäniemi VTT, Finland	*Scalable High-Resolution Printed Electronics with Reverse Offset*
T17	10:00	John Fahlteich KETMarket, Germany	*From Lab to Market – Accelerating innovation and technology transfer!*
10:15 – 10:45		**Break**	
	Chair: Daniel Corzo		**Session 5: Future Applications: Microfluidics and Sensors**
T18	10:45	Gregory Nordin Brigham Young University, USA	*Redefining Microfluidics: The Power of Advanced 3D Printing*
T19	11:15	Claudia Hackl UFZ, Germany	*Printed microfluidic membrane reactor for in-situ product recovery*
T20	11:30	Muhammad Usman Akhtar TU Munich, Germany	*3D printing of structured micro-particles with multifunctional materials for multiplex immunoassay*
T21	11:45	Ayako Yoshida Yamagata University, Japan	*Development of Sustainable and High-Performance Sensor Systems Using Printing Technology*
12:00 – 13:30		**Lunch Break**	
	Chair: Gregory Nordin		**Session 6: Emerging Microstructure Printing Techniques - Part II**
T22	13:30	Masoud Mahjouri-Samani Auburn University/NanoPrintek, USA	*Inkless multimaterial printing of electronics and functional devices*
T23	14:00	Uwe Scheithauer Fraunhofer IKTS, Germany	*Additive Manufacturing of (multi-material) ceramics opens the door to components with high functionality*
T24	14:15	Nina Szczotka XTPL, Poland	*Digital Microprinting with Ultra-Precise Dispensing (UPD) Technology: Precision Solutions for Microelectronics and Displays*
T25	14:30	Louis Caillard Hummink, France	*HPCaP Redefines Precision in Microstructure Printing*
	15:00	**Hiking tour in Saxonian Switzerland**	
	19:30	**Conference Dinner and Poster Award**	

T14

Making an impact: Scaling digital, additive processes to Electronics Production

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Type of presentation: invited talk

There are a number of hurdles when it comes to scaling new processes to industrial production, not all of which are technical in nature. At the same time, more often than not, these improvements hold great potential to reduce cost and make production more sustainable at the same time.
I will give a more abstract view on those scale-up challenges and share some insights on how we approach them in our company. I will also give concrete examples of applications in semiconductor, display, and PCB manufacturing where these challenges have been overcome successfully.
I will close with the current limitations in digital manufacturing and how we plan to overcome those to enter even more application areas.

References

www.notion-systems.com

T15

Roll-to-roll Nano-Imprinting Processes for Functional Surfaces Using Electron Beam Crosslinking

Steffen Günther[1*], Elisa Kutschke[2*]
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Type of presentation: contributed talk

In the realm of advanced material applications, functional surfaces with tailored topographies play a crucial role across various industries, including furniture design, security technology, and healthcare. This presentation highlights innovative techniques of roll-to-roll nanoimprinting (also known as nanoimprint lithography, NIL) and demonstrates their efficiency and precision in producing these surfaces.
We will explore the unique process of electron beam crosslinking combined with nanoimprinting, where liquid coatings are structured in real-time while being cured (see figure 1). Attendees will gain insights into the fundamentals of electron beam curing and its significant effects on various substrates, particularly acrylic coatings on polymers.

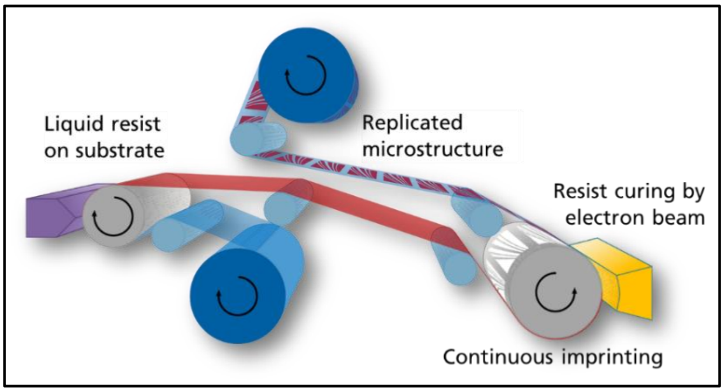

Figure 1 *Principal drawing of electron beam-based nanoimprint process including coating, imprinting, and curing/crosslinking*

Furthermore, this talk will cover the versatility of electron beam-based NIL in processing polymer films, paper, and PVD-coated materials for high-impact applications such as microfluidic systems, security holograms, and lab-on-chip devices. A closer look will be taken at a respective roll-to-roll machine designed for handling flexible substrates up to 1.25 m in width (see figure 2). We will analyze the influence of mechanical adjustments in the machine setup and critical process parameters, including temperature, speed, and electron beam dose.
Utilizing a state-of-the-art roll-to-roll line equipped with CCD cameras and microscope for 100 % surface inspection, we will present compelling results that contextualize the process within the broader landscape of industrial applications. Join us to discover how these scientific advancements can drive innovation in your projects and meet the growing demands of the market.

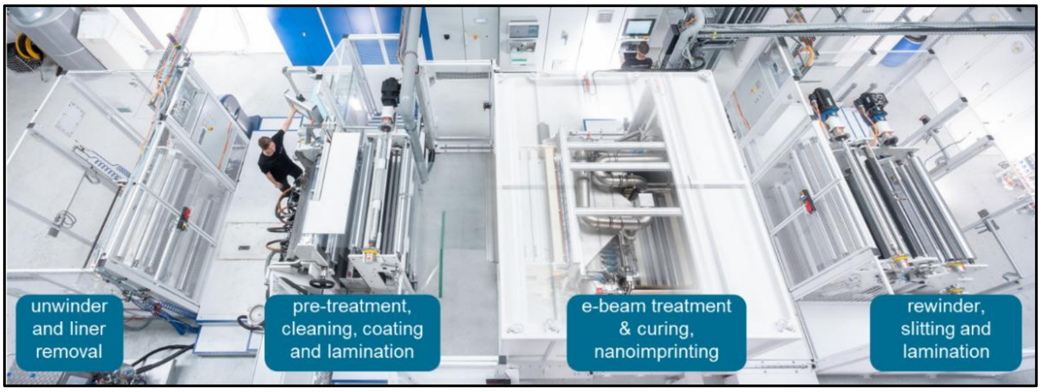

Figure 2 *Picture of roll-to-roll line consisting of 4 modules for converting, coating, slitting, and nanoimprinting of flexible substrates up to 1.25 m in width*

T16

Scalable High-Resolution Printed Electronics with Reverse Offset

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Type of presentation: contributed talk

The field of printed electronics has advanced towards maturity in many applications, ranging from solar cells, heating panels, e-ink displays, to wearable sensors. However, the printing resolution and overlay alignment accuracy of conventional, scalable printing methods (e.g. screen, flexography, inkjet) is typically >10 µm. This is not adequate for the fabrication of multilayer thin film devices that would be on par with devices made with conventional photolithography in terms of their size and performance. Novel printing methods have been developed that can provide both single µm-level printing and good overlay accuracy. Those include nozzle-based methods, e.g. electrohydrodynamic jet, ultra precise dispensing, and super inkjet, as well as methods that utilize polydimethylsiloxane-based surfaces either as patterned stamp, e.g. microcontact printing (µCP), or as non-patterned blanket to enable ink patterning in semi-dry condition, e.g. gravure offset and reverse-offset printing (ROP). For example, ROP has good potential for scalability both in large-area, single layer µm-level structures (e.g. touch panels, electrodes, antennas, metamaterials) in roll-to-roll (R2R) or in miniaturized multilayer devices (e.g. transistors, sensors, circuits) in large-volume roll-to-sheet (R2S) process.
In this work, we will compare high-resolution printing methods in terms of their scalability and potential in the fabrication of multilayer thin-film devices such as thin-film transistors (TFTs) that can be used in various applications ranging from flexible displays to biosensors [1]. We will focus our discussion on ROP, which can be used to print nanoparticle (NP) inks [2], polymers [2,3], metal oxide precursors [4], as well as polymer resist inks for patterning of vacuum-deposited (evaporated, sputtered or atomic layer deposited) metal or metal oxide thin-films [2,3]. This enables the combination of high-resolution patterning and high-performance thin films in similar way as µCP, but at a considerably larger materials palette. Here, we will discuss the fabrication of high-performance TFTs with combination vacuum deposition and ROP for patterning all the layers of the TFT devices (i.e. gate, gate dielectric, semiconductor, and source/drain electrodes) [5,6]. As an example of the good scalability of R2S ROP, single print using a printing plate made onto 200 mm Si wafer would deliver over 1000 pcs of 5 mm x 5 mm sized chips.

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From Lab to Market –
Accelerating innovation and technology transfer!

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Type of presentation: contributed talk

Bringing a new technology to market is the biggest challenge for tech-driven startups and academic spin-offs. While technological development often takes center stage, true success requires understanding the market, building a viable business model, and developing entrepreneurial and sales skills.

In this talk, we share a proven approach and a real-world example of how we successfully turned an idea into a viable business – without external investors. We will explore the key success factors: aligning technology with customer needs, developing a sustainable business model, implementing targeted sales and communication strategies, and building a reliable structure with an interdisciplinary team. We will also highlight typical challenges and mistakes along the way – and show how to overcome them with clear steps and practical strategies.

Our goal is to empower innovators to bring their solutions to market – faster, more cost-effectively, and with greater impact. This presentation offers practical insights for founders, aspiring spin-offs, and innovation professionals aiming to turn technology into real-world success – where science meets the market.

T18

Redefining Microfluidics: The Power of Advanced 3D Printing

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Type of presentation: invited talk

Harnessing 3D printing for microfluidic device fabrication is challenged by the need for sub-100 μm features, especially the negative space structures central to microfluidics. This presentation showcases custom Digital Light Processing (DLP) 3D printers and optimized materials developed to tackle these demands and push the boundaries of resolution. We introduce a generalized 3D printing method that expands the available parameter space to achieve negative feature resolutions approaching the printer's physical limits [1]. We demonstrate the application of these innovations to high-resolution passive structures (e.g., channels, mixers) and active components (e.g., valves, pumps), integrated into functional devices such as dose-response assays and cell chemotaxis chips. Example achievements include channels with 1.9 μm x 2.0 μm cross-sections and squeeze valves with 15 μm x 15 μm active area. Moreover, we introduce a new vacuum 3D printing method with which we print devices with 11,200 membrane valves, each 150 μm in diameter. We also show a multi-resolution 3D printing method with sub-micron image projection paired with lower resolution images to realize fast print times. Our new 3D printer implementations and device demonstrations highlight the potential of these innovations to redefine microfluidic fabrication.

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T19

Printed microfluidic membrane reactor for in-situ product recovery

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Type of presentation: contributed talk

The transfer of *in-situ* product recovery (ISPR) to microfluidic systems has proven to be an effective tool for realizing previously infeasible processes. A process that benefits from such a separation is the photosynthetic production of H_2 in *Synechocystis sp.* PCC 6803, which is limited due to the simultaneous formation of O_2 [1]. We have developed a microfluidic system with integrated reaction and gas channel, separated by a gas-permeable membrane. This microscale ISPR system is capable of efficiently removing the gaseous products O_2 and H_2 from the reaction channel and supporting continuous product formation. The microfluidic chip was fabricated using an inkjet-based cryo-printing approach recently introduced by us [2]. Water is used as “ink” and printed frozen ice structures act as template for the later microfluidic channels, which are sealed by a layer of a UV-curable acrylate material. The printing process was further adapted for physical gas extraction by implementing a silicone acrylate-based layer as a membrane between the printed microfluidic structures and the sealing material. Different membrane compositions, previously analyzed for their permeability to O_2 and H_2, were tested. We evaluated quantitatively the O_2 extraction rates of the different membranes integrated in the printed microfluidic chip. Therefore, an O_2 concentration gradient was established between the reaction and the gas channel. O_2 concentrations were measured via time-lapse microscopy using the phosphorescence lifetime of O_2-sensitive sensor beads, and data was extensively processed to yield the O_2 extraction rates. The main findings are: The initial O_2 flux across the gas-permeable membrane is mainly driven by the concentration gradient, while the permeability of the membrane materials provides the control variable to maximize oxygen fluxes in the later steady state. This was verified by different polymer types showing different O_2 extraction rates. We confirmed that the O_2 extraction rates are in the same order of magnitude as the O_2 evolution rates to sufficiently establish anaerobic conditions in the reaction channel. Next, we will couple O_2 generation by *Syn. sp.* PCC 6803 and membrane-based removal as a final validation of the microfluidic ISPR chip concept.

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T21

Development of Sustainable and High-Performance Sensor Systems Using Printing Technology

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Type of presentation: contributed talk

With the arrival of the IoT era, the implementation of a vast number of sensors is becoming essential. At the same time, there is an increasing demand for a circular economy that efficiently utilizes limited resources and reduces waste while achieving a sustainable society. The electronics industry is no exception. Against this backdrop, printing processes, as an additive manufacturing method that applies materials only where needed, have gained attention as an environmentally friendly next-generation technology for fabricating electronic devices. Compared to traditional subtractive manufacturing methods, printing processes offer higher material utilization efficiency and generate less waste, including waste liquids.

In this report, we present our recent progress in designing printable functional conductive composite materials for high-performance printed soft sensors. Specifically, we have developed a novel printable conductive ink composed of PDMS, carbon black (CB), and deep eutectic solvents (DES). This ink spontaneously forms a microporous conductive structure without requiring complex processing [1, 2]. Leveraging this composite material, we have successfully developed highly sensitive pressure sensors and low-hysteresis stretchable strain sensors. Furthermore, we have created conductive inks using cellulose nanofiber (CNF) and carbon, leading to the successful development of high-sensitivity, fast-response humidity sensors [3, 4]. Additionally, we have developed circuits to drive these sensors by utilizing flexible hybrid electronics (FHE) technology, which integrates printing technology with Si-LSI. These circuits are equipped with wireless communication capabilities, enabling standalone operation [5].

The integrated sensor system, combining these sensors and circuits, is characterized by its thin, lightweight, and flexible design, making it highly suitable for applications in various fields, including healthcare and robotics.

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T22

Inkless multimaterial printing of electronics and functional devices

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Type of presentation: invited talk

Printed electronics and functional devices at the micro- and nanoscale have predominantly utilized ink-based deposition techniques, such as inkjet and aerosol jet printing. While widely adopted, these methods suffer from critical drawbacks, including: (i) costly and labor-intensive ink formulation and stabilization processes, (ii) dependence on complex, pollutive, and material-specific supply chains, and (iii) the need for high-temperature post-processing steps for sintering and adhesion. These constraints introduce surfactant-related contamination, ink instability, and limited material availability. To overcome these limitations, we introduce a multimaterial additive nanomanufacturing (M-ANM) platform where nanoparticles are laser-generated and laser-sintered in situ and on demand, eliminating the need for pre-formulated inks.[1-8] This ink-free, single-step process supports the deposition of a broad spectrum of functional materials—including metals (e.g., Ag, Cu, Pt, Zn, Au), semiconductors and oxides (e.g., SnO, ZnO, TiO_2), and dielectrics (e.g., Al_2O_3)—allowing for the heterogeneous integration of hybrid structures. The printed structures exhibit high mechanical flexibility and robust electrical performance, as confirmed through bending fatigue, cyclic reliability, and adhesion testing. The M-ANM approach significantly advances the scalability, precision, and material versatility of printed electronics, with direct implications for next-generation sensors, circuits, and multifunctional devices.

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T23

Additive Manufacturing of (multi-material) ceramics opens the door to components with high functionality

***Uwe Scheithauer*[1*], *Lisa Gottlieb*[1], *Robert Johne*[2], *Steven Weingarten*[2], *Christian Berger*[1], *Eric Schwarzer-Fischer*[1]**

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Type of presentation: contributed talk

Significant advances in production technology, materials, component design and data science are driving innovation across all industries, including microprinting. Ceramic materials, customized additive manufacturing processes and novel design methods hold enormous potential for innovation due to the exceptional thermal, chemical and mechanical properties of high-performance ceramics. Additive manufacturing enables the production of complex ceramic components with unprecedented functionality. The hybridization of manufacturing technologies and materials facilitates the direct integration of additional functions such as sensors and actuators. Despite their potential, ceramic materials are still underutilized. This article aims to stimulate discussion on the use of high-performance ceramic components in the field of microprinting in order to identify suitable applications. In addition to the realization of ceramic nozzles with integrated electrical heaters or temperature sensors, highly complex fluid channels can also be realized.
The lecture will use concrete examples to demonstrate the potential of innovations in the field of materials and manufacturing technology for the additive manufacturing of high-performance ceramics.

Digital Microprinting with Ultra-Precise Dispensing (UPD) Technology: Precision Solutions for Microelectronics and Displays

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Type of presentation: contributed talk

The rapid advancement of microprinting technologies is transforming advanced manufacturing by offering unprecedented precision, flexibility, and efficiency. In microelectronics, digital printing provides innovative solutions for fabricating Through Glass Vias (TGVs), essential for vertical interconnection in high-performance devices [1,2]. Traditional TGV production methods often face challenges in achieving high aspect ratios and miniaturization. Integrating microprinting with conductive materials, such as silver paste, addresses these limitations, streamlining the production process, enhancing design flexibility, and enabling the creation of smaller, more functional devices. XTPL contributes to this advancement through its Ultra-Precise Dispensing (UPD) technology by providing microscale precision for material deposition. This technology supports various microprinting applications, including high-density microelectronics, photonic circuits, and next-generation displays. In microelectronics, UPD facilitates the filling of high aspect ratio structures with diameters ranging from 30 to 100 µm and depths up to 260 µm, achieving ratios of up to 1:5. Modifications to the silver paste improve adhesion to via sidewalls and reduce porosity, enabling the creation of complex architectures with multiple connections. Structures incorporating daisy chain configurations have demonstrated excellent conductivity, with consistent performance as the number of connections increases. Adhesion tests of silver paste on gold pads using the Scotch tape method confirmed strong bonding. In display technologies, UPD has shown remarkable potential in the deposition of red and green quantum dot (QD) inks in matrix patterns. Trials confirmed the compatibility of XTPL's Delta Printing System with various QD formulations, achieving stable, uniform matrices on glass substrates. This precise deposition system enhances wide-color microdisplays by enabling the construction of multilayer structures with photocurable materials, ensuring controlled filling of QD ink cavities with micron-level dimensions. This minimizes UV light leakage and optical crosstalk while supporting fine-pitch sub-pixel structures with high color gamut and multi-layer stacking capabilities. These developments underscore the transformative potential of combining microprinting with UPD technology to address critical challenges in microelectronics and display manufacturing, driving innovation across industries and setting new benchmarks in additive manufacturing.

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HPCaP Redefines Precision in Microstructure Printing

Achille Guitton[1], Marc Pascual[1], Maroua Ben Haddada[1], Sahar Al Kamand[1], Nathan Bigan[1], Amin M'Barki[1]*

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Type of presentation: contributed talk

In the evolving landscape of advanced manufacturing, the demand for high-resolution and high-precision printing has become increasingly critical, particularly in microelectronics, semiconductors, and display technologies. Traditional printing techniques face significant limitations in achieving resolutions below 5 µm while maintaining material and substrate versatility. Addressing these challenges, High Precision Capillary Printing (HPCaP) emerges as a groundbreaking printing technology capable of reaching sub-micron resolutions. HPCaP is inspired by Atomic Force Microscopy (AFM) and operates solely through capillary forces, allowing direct and controlled deposition of functional materials on a wide range of substrates. By leveraging a macro-resonator and cutting-edge electronics, HPCaP ensures precise adjustments in print geometry, including line width, and thickness (Fig.1) [1]. Its innovative design, featuring a glass pipette attached to a macro-resonator, enables real-time interaction between the pipette and the substrate, ensuring highly controlled dispensing without satellite drops or splashing (Fig.2). Additionally, HPCaP demonstrates remarkable material adaptability, accommodating various functional inks in microliter volumes, allowing for efficient material utilization and reduced waste [2]. It also can print on diverse substrates, including flexible and recyclable materials, broadening its application scope. HPCaP directly addresses miniaturization needs, outperforming conventional inkjet and CVD methods. In semiconductor fabrication, HPCaP enables precise deposition for metallization, microbump formation, and defect repair (Fig.2). As microfabrication continues to push the boundaries of precision, HPCaP stands at the forefront of next generation printing technologies, offering a versatile solution for producing high-resolution microstructures. With its capability to print fine patterns with sub-micron accuracy, HPCaP paves the way for advancements in microelectronics and beyond.

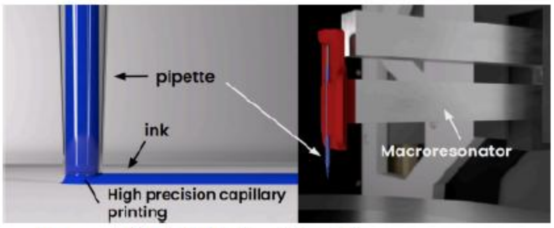

Figure 1. HPCaP Working Principle.

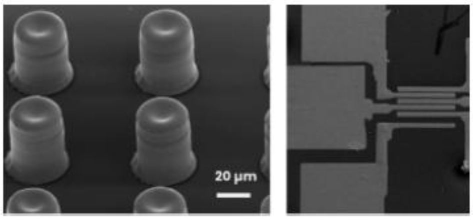

Figure 2. Bumps and Pads Printed by HPCaP.

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Program – 27th August 2025

Wednesday 27th August 2025

		Chair: Tadahiro Furukawa	Session 7: Scaling of Microprinting – Part II
T26	09:00	Sebastian Gepp Bopla Gehäuse Systeme, Germany	*High Yield production in printed electronics- route to success*
T27	09:30	Robert Kirchner Heteromerge, Germany	*In situ multi-material 3D printing of rigid and compliant materials using 2-photon-polymerization*
T28	09:45	Pia Schmiedel Henkel, Germany	*Alternative manufacturing technology: pad printing as enabler for 3D parts functionalization*
T29	10:00	Frank Roscher Fraunhofer ENAS, Germany	*Additive deposition technologies: from 2D towards 3D electronic systems*
10:15 – 11:00		**Break + Room Check out til 11**	
		Chair: Andreas Winkler	**Session 8: Future Applications enabled by 3D Printing**
T30	11:00	Callum Vidler The University of Melbourne, Australia	*From Interface to Impact: Accelerating 3D Biofabrication through Dynamic Interface Printing*
T31	11:30	Sophie Suijdendorp TNO at Holst Centre, The Netherlands	*Freeform 3D Microelectronics and Packaging by Additive Micro-Manufacturing*
T32	11:45	Alexander Blümel JOANNEUM Research, Austria	*New inhibition technology for (Pt)-cured silicones to enable 3D printing*
T33	12:00	Patrick Galliker Scrona, Switzerland	*Additive Microfabrication using InkLogic Multinozzle Printing*
12:30		**Closing remarks**	
12:45 – 14:00		**Lunch Break**	

T26

High Yield Production in Printed Electronics – Route to Success

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Type of presentation: invited talk

The presentation *"High Yield Production in Printed Electronics – Route to Success"* emphasizes that achieving high yield is the most critical factor for success in the field of printed electronics. Since costly materials such as precious metals and specialized substrates are used, every defect or scrap leads to significant financial losses. Substrates often provide functions beyond serving as carriers—such as transparency or flexibility—which makes waste reduction even more important.

High yield is particularly crucial in **transparent electronics**, which are applied in traffic monitoring, lighting, heaters, and antennas. Transparent antennas, for example, are produced with metal mesh and printed silver to balance visibility with electrical performance. Quality in these products is measured through inspections like thermal imaging, optical analysis, and frequency testing, where consistency of antenna behavior reflects overall production quality.

A major challenge lies in **microprinting**, where conductive traces as small as 65 µm in width and 85 µm in spacing must be produced reliably. While millions of such structures can be printed daily, inspection becomes the key hurdle. Errors such as ink spreading, dirt inclusions, or optical flaws can cause functional failures like electrical shorts.

To ensure yield, Phoenix Mecano employs a combination of inspection methods, including optical cameras, electrical performance testing, and thermographic imaging. Importantly, every product is tested for its main functionality before delivery.

Ultimately, the presentation underscores that in printed electronics, **yield and inspection are inseparable**. Mastery of both determines cost efficiency, product reliability, and long-term competitiveness.

In situ multi-material 3D printing of rigid and compliant materials using 2-photon-polymerization

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Type of presentation: contributed talk

3D printing is a versatile technology for prototyping and medium-volume production. Classically, feature size resolution and throughput are contradictory in such a serial technology. 2-photon-polymerization techniques are leading both in smallest feature resolution and highest throughput in terms of printed volume elements ("voxels") per time [1]. Adding the option to process multiple materials in a single print run has been a holy grail for a long time. We have a novel technology for material exchange during the print process using an open fluidic in situ process (Fig. 1) [2,3]. This allows unmatched sub-50 nm alignment accuracy between individual material sections across multiple printing scales ranging from 150 nm line width resolution to millimeter scale printing with the same alignment precision. We achieved the heterogenous printing of completely different materials, namely a polar, rigid acrylic formulation and a con-polar, compliant siloxane formulation in one single print run. We have realized a large variety of structures to demonstrate the versatility of the technology (Fig. 2). We will demonstrate results both on a direct exchange between the two materials for simplified structures as well as a process using an intermediate organic material for more complex structures. To our best knowledge this is the first time such a material combination in one single fully automated print run has been demonstrated. This paves the way towards new applications such as acoustic materials or compliant optical systems.

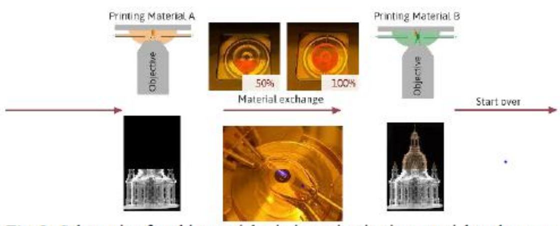

Fig. 1: Schematic of multi-material printing using in situ material exchange to combine multiple materials in one print run with ultra-high alignment precision.

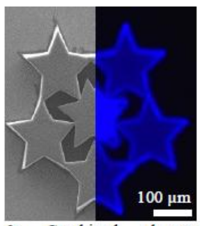

Fig. 2: Combined electron and fluorescence image of a structure consisting of rigid MX535 (central star) and compliant IP-PDMS material.

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T28

Alternative manufacturing technology: pad printing as enabler for 3D parts functionalization

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Type of presentation: contributed talk

This presentation introduces pad printing as a transformative additive manufacturing technology for functionalizing 3D-shaped components in electronics. Unlike traditional methods, pad-printable functional inks enable direct deposition onto complex geometries—eliminating the need for wires, etching, or electroplating. The session highlights key technical advantages such as high throughput, substrate adaptability, and environmental benefits. Comparative insights into screen vs. pad printable inks are provided, alongside application examples in antennas and other. Attendees will gain a clear understanding of when and how to adopt pad printing, supported by Henkel's evolving material portfolio and strategic partnerships.

Additive deposition technologies: from 2D towards 3D electronic systems

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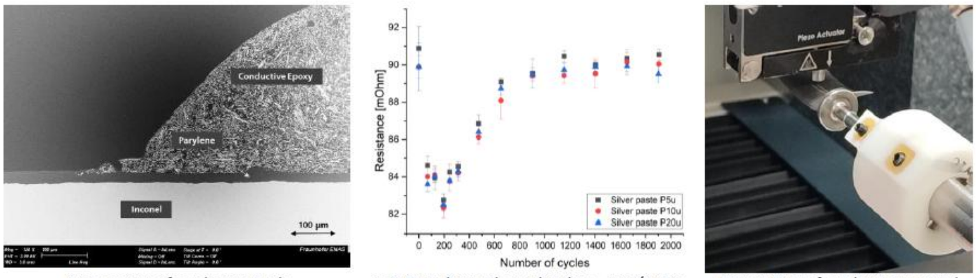
Type of presentation: contributed talk

Advancements in integrated 3D electronics are critical for the next generation of aerospace, automotive and industrial applications, where components must withstand environmental challenges while maintaining reliability. Traditional methods for fabricating conductive traces on complex shapes are limited by geometric constraints, insufficient material compatibility and durability or only limited material combinations are available. This research investigates the reliability of printed conductive traces. A layered structure of sheet metal coated with a thin conformal dielectric coating for electrical insulation and defined surface properties served as the substrate for the printing of conductive traces. Electrical resistance and morphology were monitored during thermal cycling. The goal is to develop a robust process for the deposition of reliable electrical structures on complex shapes. Envisioned applications are integrated sensor and measuring solutions in aerospace, automotive and industry. For the reliability analysis, test structures were fabricated using Inconel 718 substrates, a high-performance alloy relevant for the envisioned use cases. Parylene F was applied as an insulating coating, offering excellent dielectric and barrier properties, relatively high-temperature resistance, and conformal pinhole-free coverage on complex 3D surfaces. Conductive traces were deposited using piezo-jetting valves mounted on a Neotech AMT 5-axis tool, enabling precise 3D processing. Two conductive pastes—a medium viscosity silver paste and a high viscosity epoxy—were compared by printing and curing simple line designs. Initial electrical resistance was measured before subjecting the substrates to thermal cycling (+125/-40 °C, 40 min per temperature). At defined intervals, samples were analyzed via optical and electron microscopy and re-measured for electrical resistance. The samples remained electrically conductive after 1900 thermal cycles, demonstrating the durability of the material stack. Electrical resistance varied over the initial phase of the cycling experiment but settled and reached a plateau after roughly 250 and 1000 cycles for the epoxy and the silver paste, respectively. These fluctuations are attributed to additional sintering during the high-temperature phase of the thermal cycles and stress-induced aging and the oxidation of silver particles.



Cross-section of conductive track | *Resistivity during thermal cycling, -40°C/125°C* | *Piezo Jetting of conductive material using 5 axes motion system*

Figure 1: Overview pictures highlighting aspects of the abstract

From Interface to Impact: Accelerating 3D Biofabrication through Dynamic Interface Printing

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Type of presentation: invited talk

The advancement of three-dimensional fabrication technologies driven by demands for enhanced speed and structural complexity has yielded a diverse portfolio of printing methodologies with applications spanning rapid prototyping, microfabrication, microfluidics, and photonics. Of particular significance is the capability to generate high-resolution structures from materials traditionally considered challenging for additive manufacturing, especially in the context of biofabrication where temporal dynamics, material properties, and processing parameters exert substantial influence on final scaffold performance. Volumetric printing approaches have recently emerged to address these challenges[1,2], enabling the generation of three-dimensional constructs within seconds while employing soft hydrogel precursor materials. Nevertheless, despite the temporal advantages offered by these techniques, persistent challenges encompassing object reproducibility, optical transparency requirements, achievable feature resolution, and scalability constraints beyond single-object production continue to impede the translation of volumetric printing technologies from laboratory settings to broader industrial and pharmaceutical applications.

Herein, we present Dynamic Interface Printing (DIP)[3] as a novel, universally adaptable high-throughput manufacturing methodology that leverages a constrained air-liquid boundary as the fabrication platform, facilitating rapid production of high-resolution scaffolds across diverse material systems in seconds. Additionally, we develop an innate acoustic modulation approach of the air-liquid meniscus, which permits enhanced mass transport, microstructural control, three-dimensional cellular organization, and tunable multiphase material networks within fabricated constructs. We explore the versatility of DIP through the creation of complex fluidic manifolds, demonstration of overprinting capabilities, and direct integration into established biological workflows, thereby illustrating its potential to advance biofabrication technologies toward the scale, reproducibility and throughput necessary for industrial deployment.

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Freeform 3D Microelectronics and Packaging by Additive Micro-Manufacturing

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Type of presentation: contributed talk

Additive manufacturing of (micro) electronics is an emerging technology utilizing conventional 3D printing technology concepts in conjunction with printed electronics. The benefits of additive printing of electronics include increased digital design freedom, on-demand printing, local manufacturing, and reduced material waste. However, limited production throughput and the relatively large feature sizes limit mainstream adoption of the technology.
At TNO-Holst center, a novel additive microprinting platform has been developed with high resolution patterning of a dielectric in a layer-by-layer fashion. This enables the possibility for heterogeneous integration of conductive tracks, micro components, chips and interconnects throughout the patterned structural dielectric matrix [1]. This presentation will discuss our 3D printed microelectronics platform which uniquely combines direct imaging lithography, additive manufacturing technology, and a foil-based resin-recoating process.
Multiple demonstrators will be showcased highlighting these capabilities. One of which is presented in Fig. 1 (left), a compact endoscopic ultrasound tip featuring interconnects between bare die ASIC chips and a CMUT transducer array (collaboration with Philips within the European project AMPERE). In Figure 1 (middle), a chip fanout is shown where a bare die chip with 60 µm bond paths is embedded with printed 20 µm wide traces. As an example of additional concepts in development, a multimodal device with connections between microfluidics and electronics is showcased in Fig.1 (right).

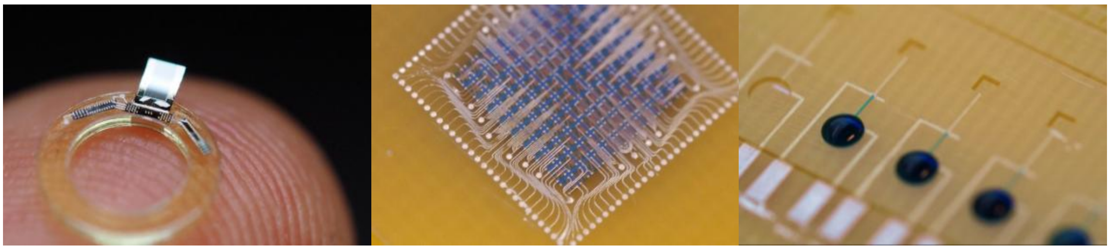

Fig. 1. Printed demonstrators including (left) ultrasound catheter attachment, (middle) chip fanout package, (right) multi-functional device with microfluidics integrated adjacent to electronics.

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New inhibition technology for (Pt)-cured silicones to enable 3D printing

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Type of presentation: contributed talk

Platinum (Pt)-cured silicones are gaining in popularity, emphasising addition curing over traditional peroxide methods. They ensure purity and efficacy, resulting in stronger and more aesthetically pleasing products. However, when curing is initiated by mixing parts A and B, the pot life is limited (minutes to hours) depending on the type of silicone and temperature. This creates practical and technological constraints such as short processing time, manufacturing waste, difficult reproducibility, and inflexible manufacturing processes.

Our patented formulation extends pot life through reversible inhibition of crosslinking - Supresil®. Unlike systems with state of the art inhibitors our inhibitors evaporate readily and completely once processing begins, even at temperatures below 80 °C, allowing normal cross-linking at mild temperatures for rapid and complete curing while maintaining the original material properties. The benefits of using Supresil® are reduced production costs, ensuring constant production quality.

Among many other applications, this technology enables inkjet printing of silicones in 3 dimensions. Very fine and complex structures are possible, making it an alternative where injection moulding is no longer feasible, either due to resolution or low part numbers.

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Additive Microfabrication using InkLogic Multinozzle Printing

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Type of presentation: invited talk

Additive Microfabrication Using MEMS-Based Multinozzle EHD Printing
Additive manufacturing techniques are increasingly shaping the future of microfabrication, offering greater versatility, reduced material waste, and novel design possibilities compared to traditional subtractive approaches. In this talk, we present a breakthrough additive microfabrication platform based on MEMS-enabled, multinozzle electrohydrodynamic (EHD) printing, developed to address current limitations in resolution, throughput, and scalability in microscale printing. The core of this technology is a highly integrated printhead with a microfabricated MEMS chip at its core comprising dense arrays of sub-micrometer nozzles capable of producing highly focused electrohydrodynamic jets. These jets enable the direct deposition of functional inks with feature sizes in the single-digit micrometer range and below, without the need for masks or post-processing steps. Unlike conventional inkjet or aerosol jet printing, this system achieves unparalleled resolution and material versatility while operating at industrially relevant throughput levels, thanks to its ability to parallelize printing across tens to hundreds or even thousands of nozzles. The talk will explore the physical principles underpinning multinozzle EHD printing, including the control of meniscus formation, electric field shaping, and ink rheology optimization. Moreover, we will highlight how recent advances in MEMS engineering, printhead design, and real-time process control have enabled stable, synchronized operation of multinozzle arrays—solving a long-standing challenge in scaling EHD printing for industrial applications.

Potential applications of this technology span a wide range of industries:

- Micro Electronics: Direct additive micro-structuring of functional features like UWB antennas even on topographic surfaces.
- Semiconductor Packaging**:** High-resolution deposition of conductive or insulating materials for redistribution layers (RDLs), micro-bumps, or interconnects.
- Flat Panel Displays**:** Fabrication of OLED or microLED pixels with precise droplet placement for high pixel densities.
- Photonic Devices**:** Patterning of optical waveguides, diffractive optics, and metasurfaces requiring nanoscale resolution.
- Biomedical Devices: Direct writing of bioinks or cell-laden formulations for microtissue scaffolds and biosensors.
- Metamaterials and 3D Microstructures: Additive creation of hierarchical geometries using conductive, dielectric, or hybrid materials.

We will conclude with a discussion on integration pathways for this printing platform into existing manufacturing lines and its potential for enabling next generation microdevices, offering a paradigm shift toward digital, maskless, and cost-effective microfabrication.